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ASSESSING HEDONIC INDEXES FOR HOUSING

Charles W. Noland

HOUSING ASSISTANCE SUPPLY EXPERIMENT

A RAND NOTE

This Note was prepared for the Office of Policy Development and Research, U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, under Contract No. H-1789. Its views and conclusions do not necessarily reflect the opinions or policies of the sponsoring agency.

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PREFACE

This note assesses a hedonic index for housing services by presenting an index fit to the St. Joseph County, Indiana, rental housing market and comparing the index with a similar one for Brown County, Wisconsin. Prepared for the Office of Policy Development and Research, U.S. Department of Housing and Urban Development, the report was presented by the author at the Western Finance Association meetings, held in San Francisco on 20-23 June 1979. The work presented here draws on research conducted by Rand as part of the Housing Assistance Supply Experiment.

The author wishes to thank C. Lance Barnett and Kevin Neels for guidance and extensive comments on earlier drafts of this note. Kevin McCarthy reviewed the final draft and provided useful suggestions. Special thanks go to Donna Betancourt, who prepared numerous versions of the note. Jane Abelson edited the final document.

This note was prepared under HUD Contract H-1789.

SUMMARY

This note presents a hedonic index fit to the 1975 rental housing market in St. Joseph County, Indiana. Comparing the index with one for Brown County, Wisconsin, shows that the two are very similar and that most of the coefficients do not differ significantly between the two indexes. The St. Joseph County index is used to examine how renters' expenditures for housing components--space, quality, location--vary with income. The patterns indicate that marginal expenditures for quality are larger than those for space and confirm the notion that higher income households give up accessibility for better neighborhoods.

Hedonic indexes were designed to facilitate the analysis of multi-dimensional commodities, i.e., those that comprise many attributes. Obtained by regressing expenditures (here monthly gross rent) on a vector of the commodity's attributes, a hedonic index yields estimated coefficients that can be interpreted as market clearing prices for the housing attributes.

The coefficients can be used as weights to aggregate the attributes of any dwelling into a single, cardinal number, which indexes the quantity of housing service provided by the dwelling. Such index numbers facilitate the comparison of disparate dwellings, form the basis of price or quantity indexes, and permit analysts to hold part of the attribute vector (e.g., site rent) constant while studying changes in the rest.

The St. Joseph County hedonic index was fit using data from the Housing Assistance Supply Experiment (HASE). The wealth of housing attributes collected by HASE makes the data base exceedingly rich and well-suited for estimating a hedonic index. The index, which contains 23 attributes describing dwellings' interiors, exteriors, and neighborhoods, performs well. It predicts monthly gross rent with a standard error of $25 (18 percent of average monthly gross rent). Although the index apparently omits some important attributes, tests show that the exclusion does not seriously bias the estimated attribute prices. Assessing the relative importance of the attributes (based on their contribution to decreasing the standard error of the estimate), we find

that housing quality ranks first, followed closely by space. Location attributes are least important.

The existence of comparable data for the two HASE experimental sites, which exhibit strikingly different market characteristics, provides a rare opportunity to investigate index portability, i.e., how similar the specifications are for different markets and how stable the coefficients are across markets. Given the differences between the two markets, the degree of portability is surprising. Over half the variables in each site's index appear in the other. When the Brown County specification was fit to data for both sites, only one coefficient had different signs, and over three-fourths of the independent variables had statistically indistinguishable coefficients. The dissimilarities, however, are significant enough to substantially affect the index's predicted values and should indicate to analysts the dangers of applying an index developed in one market to a market with different supply or demand characteristics.

Renters' expenditure patterns confirm the importance hierarchy of summary attribute groups and are consistent with the patterns frequently discussed in urban housing literature. In addition, the expenditure analysis provides an excellent example of hedonic indexes' usefulness for analyzing multidimensional commodities.

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I. INTRODUCTION

This note assesses a hedonic index of residential services fit to 1975 data for the St. Joseph County, Indiana, rental housing market. The work it reports is part of a larger research effort--the Housing Assistance Supply Experiment (HASE), being conducted by The Rand Corporation for the U.S. Department of Housing and Urban Development.

A hedonic index is the result of regressing dwellings' market values on their housing and location attributes. If certain conditions are met, the estimated coefficients can be interpreted as prices. The prices provide a means of coalescing housing attributes into a cardinal number--summarizing the amount of services supplied--that allows the comparison of dwellings across time or space, in turn facilitating the construction of price or quantity indexes. The index's structure permits analysts to distinguish differences in service flows from rental variation related to either owners' or occupants' characteristics and to distinguish housing services from site services.

HASE was conducted in two experimental sites having significantly different market conditions, Brown County, Wisconsin, and St. Joseph County, Indiana. Brown County, whose central city is Green Bay, has had a persistently tight market. Vacancy rates in St. Joseph County, whose central city is South Bend, have ranged up to 12 percent near downtown. A hedonic index similar to the one presented in this paper has already been fit for Brown County.* If the two sites' indexes were identical, the single specification could be used to analyze cross-site expenditure differences, controlling for quantity differences and location rents, and to provide upper and lower bounds to a quantity index.** Such a situation, defined as complete portability

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*See C. Lance Barnett, *Using Hedonic Indexes to Measure Housing Quantity*, The Rand Corporation, R-2450-HUD, October 1979.

**For a description of this technique, see C. Lance Barnett, *Using Hedonic Indexes to Measure Supply Response to Housing Allowances*, The Rand Corporation, WN-8686-HUD, August 1976 (forthcoming as N-1069-HUD), pp. 53-64.

of the index, would have profound implications for fitting hedonic indexes in other housing markets. The rich, marketwide housing data for the two HASE sites furnish an unusual opportunity to evaluate the index's portability, a task not only necessary for future HASE analysis but also of interest to any researcher planning to apply a hedonic index to a market other than the one in which it was developed.

Because they estimate prices for individual attributes, hedonic indexes permit the analysis of expenditure patterns for summary attribute groups such as space, quality, and location. Thus we can go beyond merely describing how total housing expenditures change with income, for example, and look at how outlays vary for the major components of housing.

Future research will be directed at improving the fit of the hedonic index for St. Joseph County and lessening its specification error. Plans also call for fitting similar indexes with data for owner-occupied dwellings in both St. Joseph and Brown counties.

THE THEORY OF HEDONIC INDEXING

Housing's heterogeneous nature hampers housing market analysis. Housing comprises a bundle of attributes, the mixture of which varies across units. For example, dwellings differ according to number and type of rooms, amount of storage space, interior layout, location, and so on. Because some element of the attribute vector (if only location) will vary between dwellings, no two are identical.

Such heterogeneity calls into question the very existence of a market equilibrium. Classical theory requires that a large number of identical units of a commodity be traded in order to establish a market clearing price, i.e., markets must be "thick." Hedonic theory asserts that individual housing attributes, rather than a specific bundle of them representing a dwelling, enter consumers' utility functions. If enough dwellings with varying amounts of the attributes are traded, normal market transactions can set prices that equate supply and demand for each attribute individually and for all attributes jointly.*

*The existence of competitive equilibrium in the context of indivisible, heterogeneous commodities is demonstrated in Andreu Mas-Collel, "A Model of Equilibrium with Differentiated Commodities,"

The hedonic index's weights can be estimated by regressing a measure of each dwelling's market value (monthly gross rent here) on its attributes. The regression coefficients are interpreted as prices for the attributes. This interpretation rests on a theory of consumer preferences for the attributes of multidimensional commodities. For a perfectly competitive market in longrun equilibrium, the vector of attribute prices is the solution to the simultaneous equation system composed of many individual demand and supply functions. Attribute prices thus represent the market's consensus about marginal rates of substitution among the attributes and are marginal prices facing both consumers and suppliers.

The lack of perfect information in the real world means that housing markets are never truly in longrun equilibrium. Consequently, actual prices are distributed around the market clearing prices. If the distributions are tight--have low variances--the estimated coefficients, which are the expected prices,* can be interpreted as the prices that would prevail in a competitive equilibrium. On the other hand, if the distributions are diffuse, the estimated coefficients have little usefulness for describing housing markets. The latter situation does not pertain to this analysis because we judge that St. Joseph County's housing market is close enough to longrun equilibrium

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Journal of Mathematical Economics, Vol. 2, 1975, pp. 263-295. For an application to urban housing markets, see Bryan Ellickson (with Barry Fishman and Peter A. Morrison), *Economic Analysis of Urban Housing Markets: A New Approach*, The Rand Corporation, R-2024-NSF, July 1977.

*A generalized least squares procedure provides the most efficient estimators for a random coefficients regression model. Even though ordinary least squares (OLS) is less efficient, it is used here for three reasons. First, it provides unbiased estimates of the price distribution means. Second, the maximum likelihood technique required to estimate random coefficient regression models is expensive and its validity rests on the assumption of independent price distributions, which seems highly unlikely in our case. Finally, we judge that the St. Joseph County rental market is not so far from equilibrium as to do great damage to the OLS estimators' efficiency. Nonetheless, using OLS will yield less efficient estimates for the prices specifically and the index in general. Moreover, the further a market is from equilibrium (i.e.,

for us to view the estimated coefficients as market clearing prices.*

Current theory gives no definitive answer to the question of the index's functional form.** At least for some attributes (e.g., number of rooms), measures expressed in natural units can introduce nonlinearities into the index. As a consequence, marginal prices will not equal average prices, which is troublesome because regressions yield estimated coefficients that are most easily interpreted as average prices. This analysis transforms attributes as needed so that their marginal and average prices will be equal. The functional form consistent with such prices is linear:

$$R_i = x_i\beta + z_i\gamma \ , \qquad (1)$$

where R_i = rent for dwelling i,

x_i = a $1 \times k$ vector of housing attributes for dwelling i,

β = a $k \times 1$ vector of housing attribute prices,

z_i = a $1 \times g$ vector of location attributes for dwelling i,

γ = a $g \times 1$ vector of location prices.

The linear form affects the interpretation of attribute prices. First, an attribute's price is, by specification of the unit of account, made independent of the quantity consumed. Second, the price of any given attribute does not vary with the quantities of other attributes. For

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the larger the variance of the price distributions), the larger will be the estimators' variances. For more on random coefficient regressions, see Henri Theil, *Principles of Econometrics*, John Wiley and Sons, Inc., New York, 1971, pp. 622-627; and P.A.V.B. Swamy, "Efficient Inference in a Random Coefficient Regression Model," *Econometrica*, Vol. 38, March 1970, pp. 311-323.

*Whereas residential properties' real values dropped fairly steadily in St. Joseph County between 1961 and 1971, by 1974 they appeared to have stabilized somewhat. See *Third Annual Report of the Supply Experiment*, The Rand Corporation, R-2151-HUD, February 1977, pp. 67-70.

**See, for example, Sherwin Rosen, "Hedonic Prices and Implicit Markets," *Journal of Political Economy*, Vol. 82, 1974, pp. 34-55.

example, the cost of a thousand square feet of lot is independent of the quality of the neighborhood.

Equation (1) readily converts to a regression equation,

$$R_i = x_i\beta + z_i\gamma + \varepsilon_i \,, \tag{2}$$

where ε_i is a random error term. The random variation in the price of residential services, represented by the error term, results from the fact that market participants are unlikely to have complete information.*

THE ST. JOSEPH COUNTY DATA BASE

Data for the hedonic index were assembled from the baseline household, residential building, neighborhood, and landlord surveys.** The household survey provided counts of rooms, interior quality ratings, evaluations of plumbing, heating, and electrical systems, indicators of the presence of various items in the unit (e.g., a thermostat), occupants' characteristics, and occupants' perceptions of the neighborhood. The residential building survey furnished exterior quality ratings, indicated the type of exterior construction material, and described the property and its blockface. The neighborhood survey supplied descriptions and evaluations of neighborhood characteristics. Landlords indicated whether or not they resided on the property and provided their assessments of building and neighborhood quality.

The hedonic index is fit to an analysis file that contains records for 1,129 rental units. Initially, household and landlord surveys were

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*In practice, the error term contains the effects of excluded attributes as well as random variation. Section II discusses this problem in greater detail.

**Those surveys were fielded in 1975 at the beginning of the allowance program to provide a benchmark for assessing its effect. The landlord survey was addressed to owners of a marketwide probability sample of rental residential properties. The household survey solicited information from the occupants of dwellings on those properties. Trained fieldworkers evaluated building exteriors for the residential building survey. As part of the neighborhood survey, local public sources were used to obtain facts on each of the 86 neighborhoods into which St. Joseph County was divided. The neighborhood survey also includes fieldworkers' reports on the characteristics of each blockface in the county.

addressed to a panel of St. Joseph County properties containing 2,737 rental units. From that set, we chose only those units with complete tenant, landlord, and residential building records, thereby excluding 1,308 units. Next, because rooming houses, lodger units, mobile homes, units on farms, and units whose occupants received rent waivers present special analytical problems, we excluded those 203 units. An additional 30 records were eliminated because they lacked data on the dependent variable, monthly gross rent; and finally, 67 records were dropped because they were missing data on some of the 200 analysis variables that were candidates for inclusion as independent variables.

Table 1 gives the sample distribution across the original sample-selection strata at each stage of the attrition described above. Compared with the panel, the final analysis sample overrepresents single-family units (especially those with medium to high rent) and underrepresents units on large properties (with 5 or more units) and those in rural areas. Nonetheless, the differences are not large: The proportion of the sample in a stratum never changes by as much as 6 percentage points, and usually by less than 2. The most significant differences occur between stages 1 and 3, i.e., when units with incomplete survey records and units that present special analytical problems were eliminated. Almost no change in the distribution results from excluding records with missing values for the dependent or independent variables.

Shrinking from the baseline panel to the analysis sample would bias our regression results only if the exclusion criteria were correlated with the dependent variable, and we have no a priori reason to believe that this is so. If surveys were completed systematically for either high or low rent units, we would have cause for worry. But Table 1 indicates that at most, such correlation is slight. There is no reason to presume that the absence of data for independent variables correlates with rent. And only 30 records were dropped because they lacked rent data, too few to seriously affect the results, even if their rents differed systematically from those of the remainder. We conclude that the sample attrition described above does not seriously bias the results presented in this note.

Table 1

COMPOSITION OF THE ANALYSIS SAMPLE
AT EACH SELECTION STAGE

Sampling Stratum[a]		Distribution (%) of the Sample at Stage:[b]				
Number	Description	1	2	3	4	5
	Urban Rental					
	Single-family:					
1	Low rent	4.1	4.5	4.6	4.4	4.5
4	Medium rent	10.7	13.8	14.2	14.0	14.5
7	High rent	6.5	11.1	11.9	12.0	12.4
	2-4 units:					
2	Low rent	19.0	18.7	20.6	21.0	20.5
5	Medium rent	19.0	17.8	20.0	20.1	20.8
8	High rent	5.0	4.1	4.2	4.2	4.4
	5+ units:					
3	Low rent	10.3	9.1	9.3	9.0	7.7
6	Medium rent	6.7	5.0	4.3	4.3	4.5
9	High rent	6.3	4.4	4.8	4.9	4.6
	Rural Rental					
10	Low or medium rent	6.7	6.6	5.2	5.4	5.4
11	High rent	2.4	2.3	.7	.7	.7
	Other Residential					
17	Rooming house	.3	.2	--	--	--
18	Mobile home property[c]	2.9	2.2	--	--	--
	All strata[d]	100.0	100.0	100.0	100.0	100.0

SOURCE: Tabulated by the author from baseline household, residential building, landlord, and neighborhood surveys for St. Joseph County.

[a] Strata 12-16 contain owner-occupied units, none of which were included at any stage of this analysis of rental housing.

[b] The sample-selection stages are as follows:

1. Total baseline rental sample ever scheduled for interviews.
2. Excludes units lacking a field-complete household, landlord, or residential building survey.
3. Excludes farms, mobile homes, rooming houses, properties with mixed tenure, and any unit whose occupants receive rent reductions or who occupy their unit rent-free.
4. Excludes units with missing values for the dependent variable.
5. Excludes units with missing values for any independent variable.

[c] Properties on which 75 percent or more of all dwellings are mobile homes. Most are mobile home parks that rent spaces to vehicle owners.

[d] Components may not sum to 100.0 because of rounding.

PREVIEW OF THE RESULTS

Section II describes the variables in the St. Joseph County index, presents their coefficients, and investigates the relative importance of attribute groups in the index. The specification comprises 23 housing attributes--measures of space, housing quality, and location--and three price adjustment variables to account for systematic deviations from market price. Based on each attribute group's contribution to reducing the standard error of the estimate, housing quality is the most important group, followed closely by space; location is least important. Tests indicate that although the specification excludes some important attributes, the omission probably does not severely bias the estimated coefficients.

Section III assesses index portability by comparing the specifications with the best fit in each site and by comparing the same specification in both sites. Both approaches suggest considerable index portability: Over half of the independent variables in each site's index are common to both; and when the same specification is fit in both sites, over three-quarters of the estimated prices are statistically indistinguishable between sites. Nonetheless, some notable differences in both comparisons suggest caution before using either site's index in the other site.

Section IV investigates renters' expenditure patterns for attribute groups, showing that as income increases, marginal expenditures for housing quality are larger than those for space. Marginal expenditures on location evidence a slight tendency to decrease at first and then increase. That pattern results from the fact that renters spend less for accessibility and more for neighborhood quality as income increases, the former effect being less pronounced in the upper income ranges.

Section V summarizes the findings, discusses data problems, proposes solutions to these problems, and considers directions for future research.

II. THE ST. JOSEPH COUNTY HEDONIC INDEX

The literature on hedonic indexes as well as a priori reasoning guided the choice of candidate variables. Experience and observation provided the starting point for identifying attributes that contribute to the supply of residential services. Earlier hedonic indexes for housing furnished empirical support for many of the variables chosen on a priori grounds and suggested additional candidates.*

For theoretical reasons, we excluded variables that identify attribute demand or supply. As explained in Sec. I, the hedonic index represents the reduced form solution to the simultaneous system of demand and supply equations. Including such variables as the tenant's income or the price of land would tend to identify the demand or supply relationships.

Practical considerations also affected the variables that went into the index. Using over 400 survey items, we constructed some 200 analysis variables, most of which were tested for inclusion in the index. Where necessary, variables were rescaled so that their average and marginal prices would be equal.** Some individual ratings were replaced with averages for logically grouped features to forestall collinearity problems that would arise from using the individual ratings.

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*See, for example, John F. Kain and John M. Quigley, "Measuring the Value of Housing Quality," *Journal of the American Statistical Association*, Vol. 64, June 1970, pp. 532-548; A. Thomas King, *Property Taxes, Amenities, and Residential Land Values*, Ballinger Publishing Company, Cambridge, Mass., 1973; Mahlon R. Straszheim, *An Econometric Analysis of the Urban Housing Market*, National Bureau of Economic Research, New York, 1975; James T. Little, "Residential Preferences, Neighborhood Filtering and Neighborhood Change," *Journal of Urban Economics*, Vol. 3, January 1976, pp. 68-81; Allen C. Goodman, "Hedonic Prices, Price Indices, and Housing Markets," *Journal of Urban Economics*, Vol. 5, October 1978, pp. 471-484; Sally Merrill, *Draft Report on Hedonic Indices as a Measure of Housing Quality*, AAI 76-96R, Abt Associates, Cambridge, Mass., 23 December 1977.

**For example, if additional rooms have declining marginal value in the market, then rooms should be rescaled to account for that. Here, the natural logarithm of the number of rooms is used, a transformation that incorporates declining marginal value.

Only variables whose coefficients' t-values exceeded 1 were included in the regression. Satisfying that condition minimizes the standard error of the estimate and hence the index's prediction error.* Reducing both errors increases the accuracy with which the index can measure the quantity of housing and location services.

Dwelling attributes fall into two natural groups--housing attributes (those relating to the dwelling and its property) and location attributes (those relating to the dwelling's location and the surrounding properties). We separate housing attributes into space and quality to reflect the distinction between quantity and quality. The three location-attribute subgroups--accessibility, neighborhood quality, and blockface quality--correspond to successively smaller geographical areas.

In addition to housing and location attributes, other factors may affect a dwelling's rent. For example, landlords often raise rents more when tenants move than they do for current tenants; thus tenants may enjoy price discounts related to their length of stay in the unit. Dwellings on properties with resident landlords generally rent for less than otherwise comparable dwellings. The regression includes variables to adjust for such systematic price variations.

Table 2 presents the estimated coefficients for the independent variables in the hedonic regression.** The dependent variable is monthly gross rent (contract rent plus tenant-paid utility expenses), so that the estimated coefficients are interpreted as prices expressed in dollars per month. The next part of this section explains how the independent variables were constructed and discusses their coefficients.

SPACE

The two measures of space--number of rooms (excluding bathrooms) and number of bathrooms--were among the most significant variables in the regression. Both were transformed so that their marginal prices

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*See Yoel Haitovsky, "A Note on the Maximization of $\bar{R}^2$," *The American Statistician*, Vol. 23, 1969, pp. 20-21.

**The regression results presented in Table 2 were obtained using a generalized least squares procedure to account for the fact that the standard error of the residuals varied systematically by property type. The Appendix (Table A.1) gives the coding system for the variables as well as their means and standard deviations.

Table 2

ESTIMATED COEFFICIENTS FOR THE ST. JOSEPH COUNTY HEDONIC INDEX

Independent Variables	Estimated Price ($/mo.)	t-value
Housing Attributes		
Space		
Number of rooms (ln)	59.19	20.60
Number of bathrooms (squared)	15.75	8.44
Quality		
Number of appliances supplied by landlord (squared)	2.10	9.15
Presence of thermostat	8.11	4.45
Building age (years)	-.86	-5.64
Building age (years squared)	.005	3.61
Lot size per dwelling (1,000 square feet)	1.51	3.25
Single-family dwelling	8.48	3.09
Composite rating of comparative building quality	4.85	2.47
Presence of commercial unit in building	-8.45	-1.86
Presence of brick or stone exterior	3.83	1.53
Location Attributes		
Accessibility		
Generalized access to employment	12.45	5.93
Neighborhood Quality		
Composite rating of neighborhood quality	8.13	2.10
Located in southeast suburbs	28.61	3.54
Located in central South Bend	-5.24	-2.32
Blockface Quality		
Presence of other residential land	11.75	1.99
Presence of mixed residential and commercial land	5.50	2.47
Presence of farmland	-11.95	-1.98
Presence of abandoned buildings or vehicles	-5.31	-2.32
Presence of vacant lots	-4.54	-2.84
Presence of commercial land	-2.39	-1.47
Composite rating of buildings, yards, and property maintenance	3.35	1.73
Street maintenance	1.66	1.32
Price Adjustments		
Length of stay (years)	-4.37	-6.39
Length of stay exceeding 3.5 years	3.42	4.24
Presence of a resident landlord	-5.51	-2.37
Other		
Constant term	-.38	-.03

SOURCE: Tabulated by the author from 1,129 records composed from baseline household, residential building, landlord, and neighborhood surveys for St. Joseph County, Indiana.

NOTE: Analysis uses only data for dwellings whose occupants pay full rent and with complete information on the variables listed. "Presence of..." and "location in..." variables take the value 1 when the condition is met, zero otherwise. Composite ratings range from 0-3, except for building quality (0-2). See Appendix for variable ranges, means, and standard deviations. The standard error of the estimate = 24.55; R^2 = .64; and F = 76.68 with 26 and 1,102 degrees of freedom.

would be constant, the transformations being verified by analysis of the residuals.

To reflect the presumption that additional rooms have declining marginal value, a presumption substantiated by most hedonic studies, the number of rooms* is rescaled by taking the natural logarithm. The estimated price of the transformed variable is the most significant in the regression.

The squared specification for the number of bathrooms** was suggested by analysis of the residuals, indicating that bathrooms have increasing marginal value. Although other studies have not found this result, the age of St. Joseph County's housing stock, much of which dates from before 1930, suggests an explanation. If old dwellings were typically built with one or fewer baths, bathrooms added after construction would cost more than if they had been part of the structure originally. The presence of one bathroom adds about $16 to monthly gross rent, but two bathrooms add $64 to rent (over a unit with no baths). Thus, the second bathroom is worth $48. The coefficient is highly significant, having the third largest t-value in the regression.

QUALITY

The hedonic index includes eight housing quality attributes. The first two are interior items. The third, age of the dwelling, is a proxy for both interior and exterior quality. The final five attributes describe the unit's exterior.

The first quality attribute indicates the number of appliances supplied by the landlord up to a maximum of five--stove, refrigerator, dishwasher, air conditioner, and disposal. Residuals analysis showed that the squared specification best fit the data. The $2 coefficient indicates that, for example, a dwelling with three landlord-supplied

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*Efficiencies with complete kitchen facilities are assumed to have 1.5 rooms.

**Half bathrooms are given a value of .5 and added to the full-bathroom count. A half bathroom has a flush toilet, a bathtub, or a shower, but does not have all the facilities of a full bath.

appliances rents for $18 more per month than one with none. The coefficient has the second highest t-value in the regression.

The presence of a thermostat in the dwelling adds about $8 to monthly gross rent. Although dummy variables for various types of heating systems and a tenant-supplied rating of the heating system's quality were tested, none was significant.

A dwelling's age was used as a proxy for its quality because composite ratings of interior and exterior dwelling quality did not perform well in St. Joseph County. The coefficient of the squared term indicates that quality declines at a decreasing rate with age.* The fitted relationship implies that five year old dwellings rent for $4 less per month than new ones, while fifty-five year old dwellings rent for about $2 less than those fifty years old. The maximum decline in quality occurs at ninety-five years, when dwellings rent for $41 less than new ones.**

The amount of outdoor space available to tenants is measured by the lot size per dwelling (in thousands of square feet). It is truncated at 10,890 square feet (1/4 acre) because previous regressions showed that beyond this limit lot size makes no additional contribution to the quantity of services. The estimated price, which has the largest t-value among the exterior quality attributes, indicates that each additional 1,000 square feet adds about $1.50 to monthly gross rent.

Single-family houses command a monthly premium of $8.50 over all other property types. That premium is consistent with the fact that the market values privacy and quiet, which tend to be associated with single-family houses. Dummy variables identifying additional types (defined by the number of units on the property) were all insignificant.

Landlords, tenants, and trained fieldworkers evaluated the condition of the sampled buildings relative to surrounding buildings. The average of the three evaluations forms the composite rating of comparative building quality. Increasing values correspond to better

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*This specification, used by King in his study of New Haven, was substantiated by our residuals analysis.

**Only 17 dwellings in the sample are over ninety-five years old.

comparative ratings for the subject building. Units in higher quality buildings (in this relative sense) rent for more than those in lower quality buildings.

Units in buildings that also contain commercial space rent for about $8.50 per month less than others, while those in buildings with brick or stone exteriors rent for nearly $4 per month more.

LOCATION ATTRIBUTES

The regression equation includes location attributes to avoid estimating biased prices for housing attributes and to decompose gross rent into the portions paying for location service and for housing service. Location service is measured by accessibility, neighborhood quality, and blockface quality.

Accessibility

A dwelling's proximity to employment in St. Joseph County is measured by a neighborhood-level variable called generalized access to employment, defined as:

$$A_i = \tilde{A}_i - \min_t \{\tilde{A}_i\}$$

$$\tilde{A}_i = ln\ (E_i + \sum_{\substack{j=1 \\ j \neq i}}^{86} E_j/d_{ij}); \qquad i = 1, \ldots, 86,$$

where A_i = generalized access to employment for neighborhood i,
$\tilde{A}_i$ = a temporary variable,
ln = the natural logarithm,
$E_{i,j}$ = employment* in neighborhood i or j,
d_{ij} = the airline distance in miles between the centroids of neighborhoods i and j,
i,j = index of the 86 neighborhoods in St. Joseph County.

*Estimated from responses to the household survey's place-of-work questions.

For each neighborhood, we weight the number of jobs in all other neighborhoods by the inverse of their airline distance from the subject neighborhood and add the resulting weighted sum to the neighborhood's employment. Accessibility is thus directly related to the county's overall employment level and inversely related to how far away the jobs are. Logarithmically transforming that sum makes successive increments to employment have declining effects on access. Finally, subtracting the minimum value arbitrarily rescales access so that its minimum value is zero.*

Access to employment has a positive price, probably because increased access lowers commuting costs. That relationship is consistent with the traditional negatively sloped rent gradient.** Here, a dwelling with average access rents for about $24.50 more per month than one with minimum access.

Neighborhood Quality

Trained fieldworkers evaluated the buildings, yards, and cleanliness of each blockface in St. Joseph County.*** The blockface ratings for each item were averaged into neighborhood-level ratings. These neighborhood building, yard, and cleanliness ratings were then averaged into an overall neighborhood quality rating, the estimated coefficient of which shows that better neighborhoods supply greater location service.

We would like to have additional neighborhood quality measures such as population characteristics and indicators of local amenities and service levels. However, no coefficients of the variables tested so far were significant. Pending the resolution of multicollinearity

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*Access to employment is not the only attribute with an arbitrary zero point. In particular, the quality ratings all have arbitrary zero points, the effects of which are discussed below.

**See William Alonso, *Location and Land Use*, Harvard University Press, Cambridge, Mass., 1964; and Richard F. Muth, *Cities and Housing*, The University of Chicago Press, Chicago, 1969.

***Except for comparative building quality, all ratings are coded on a four-point scale: 0, poor; 1, fair; 2, good; and 3, very good.

and measurement error problems,* the index includes dummy variables identifying the best and worst areas of the county--the southeast suburbs and central South Bend, respectively. The coefficients (a $29 per month premium and a $5 per month discount) imply that the quality rating alone does not adequately control for neighborhood differences.

Blockface Quality

The first six blockface variables indicate the presence of various items or types of land use on the dwelling's blockface.** Because the items are not mutually exclusive, the dummy variables do not have one excluded category. Rather, the excluded class for each type of land use is its absence on the blockface. The presence of other residential land or mixed residential and commercial land increases rent, while farmland, abandoned buildings or vehicles, vacant lots, and commercial land all lower rent.

The desirability of living on a blockface with other residential land--as opposed to one containing no other completely residential property--is indicated by the large positive coefficient of this variable--nearly $12. It is difficult to explain why mixed residential and commercial land also increases rent, but the coefficient remained significantly positive in all versions of the regression.

Abandoned buildings or vehicles, vacant lots, or commercial land all tend to decrease the desirability of a dwelling's blockface. Although dwellings surrounded by farmland generally are near the county's periphery, after controlling for accessibility and other quality differences, we had no reason to expect either a positive or negative

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*Many neighborhood quality variables in the HASE data base are collinear and, particularly those provided by landlords and households, "noisy." Both problems lead to underestimates of the coefficients, making it difficult to obtain significant coefficients. For an assessment of the problem and a proposal for future research, see Sec. V. Neighborhood population characteristics have not yet been tried in the regression, but plans call for their inclusion in future work.

**In rural areas, blockface variables refer to the area within a 1/4-mile radius of the dwelling.

coefficient for the presence of farmland. The large negative coefficient may indicate that the variable serves as a proxy for excluded (detrimental) rural attributes, that rural dwellings tend to be of lower quality than their age would indicate, or that the employment access is not an adequate measure of accessibility in rural areas.

The composite rating of buildings, yards, and property maintenance is the average of tenant, landlord, and trained observer evaluations of adjacent buildings and yards, their maintenance, and the amount of litter in the area. Area street maintenance was evaluated by trained observers. Both variables have positive coefficients, so that residents of areas with higher ratings pay higher rents.

PRICE ADJUSTMENTS

As explained in Sec. I, most of the variation in the price of residential services is random. Some, however, can be explained by tenant or landlord characteristics. The regression includes variables that adjust the actual prices to equal the market clearing prices.

The Brown County hedonic index has shown that as a tenant's length of stay in a dwelling increases, his rent drops relative to the rent paid by new tenants.* One explanation for this is that longer tenancy may reduce maintenance requirements, with landlords returning at least part of the savings as discounts. Another explanation is that landlords may value the steady income provided by these tenants, buying that stability with rent discounts.

The effect of tenants' length of stay on gross rent is modeled with a spline function that bends at 3.5 years. Up to that point, each additional year of residence reduces monthly rent by about $4.40. After 3.5 years, rent ceases to decline.** The maximum discount equals $15 per month, or about 11 percent of average monthly gross rent.

The presence of a resident landlord on the property lowers rent by $5.50 per month. Landlords who live on their property may choose

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*See Barnett. The hedonic index fit by Abt Associates showed the same result (see Merrill).

**Spline functions are piecewise linear. Along the jth piece the slope equals the sum of slopes of the previous $j - 1$ pieces plus the slope of the jth piece. When length of stay exceeds 3.5 years, the slope is -4.37 + 3.42 = -.95, which is not significantly different from zero.

tenants more carefully than other landlords because their tenants are also their neighbors. If so, they might try to attract desirable tenants by offering rent discounts.*

IMPORTANCE OF ATTRIBUTE GROUPS

We can measure an attribute's relative importance by determining how much it contributes to decreasing the standard error of the estimate.** For practical reasons, we limit the comparison to summary groups--space, housing quality, location, and price adjustments. Each group's effect on the standard error of the estimate provides a measure of its contribution to improving the index's prediction accuracy.

The last row of Table 3 lists the groups, ordered from least to most important. Importance was measured by a four-step procedure that, at each step, dropped the group whose exclusion least increased the regression's standard error.*** For example, location attributes were eliminated at the first step because their exclusion least damages the regression's prediction accuracy (increasing the standard error of the estimate by less than 4 percent). At the next step, each of the three remaining groups was dropped in turn to discover which one least affected the standard error. The resulting importance hierarchy is presented in Table 3.

Housing quality attributes are the most important group, followed closely by space. Price adjustments are a distant third, and location attributes fall last. This ranking is similar to the one for the Brown County index.† It also follows the pattern of marginal expenditures

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*An alternative explanation (argued from the demand rather than the supply side) is that tenants find resident landlords to be a nuisance and will pay less for dwellings on properties with resident landlords.

**Merely comparing the coefficients tells us little, as they depend on the units of measurement. The usefulness of beta coefficients depends on the independent variables' orthogonality. Given the amount of collinearity in our data, it seems wise not to use beta coefficients.

***Dropping a summary group means excluding from the regression all of the variables that compose it.

†The Brown County index distinguishes interior and exterior quality. Interior quality ranks first, space second, and exterior quality third; location attributes are least important.

Table 3

MARGINAL AND CUMULATIVE EFFECTS OF EXCLUDING SUMMARY ATTRIBUTE GROUPS ON THE INDEX'S STANDARD ERROR

Excluded Summary Attribute Groups	Standard Error ($/mo.)	Change in Standard Error from	
		Preceding Regression ($/mo.)	Full Regression[a] ($/mo.)
None	24.55	--	--
Location	25.44	.89	.89
Location, price adjustments	26.77	1.33	2.22
Location, price adjustments, space	32.71	5.94	8.16
Location, price adjustments, space, quality[b]	40.68	7.97	16.13

SOURCE: Tabulated by the author from 1,129 records composed from baseline household, residential building, neighborhood, and landlord surveys for St. Joseph County, Indiana.

[a]The hedonic index reported in Table 2 with no exclusions, represented by the first line of this table.

[b]This amounts to excluding all independent variables from the regression. The reported standard error is just the standard deviation of the dependent variable, monthly gross rent.

reported in Sec. IV, where the index is used to investigate renters' marginal expenditures for attribute groups. As household income rises, expenditures for quality increase most, those for space increase next most, and location expenditures show little change.

APPRAISING THE INDEX

The standard error of the estimate measures how closely the regression equation fits the data and indicates the degree of confidence with which the regression can estimate rent or measure differences in the amount of services supplied or consumed. As shown in Table 4, the St. Joseph County index compares favorably with others, although it does not perform as well as the Brown County index.

The regression's nontrivial standard error raises the question whether the errors are systematic or random. Either incorrectly specifying attributes' functional forms or excluding important attributes from the regression would generate systematic errors. On the other hand, if the errors are random, the index ought to be unbiased.

To assess the attribute specifications, we checked plots of the residuals against the predicted values of the dependent variable and against the independent variables. The results led to changing the specification of some attributes.* The plots indicate that the current specifications introduce no systematic errors.

To test for the exclusion of important attributes, we regressed the residuals, which contain any excluded attributes, on total household income. Because most attributes are economic "goods," their consumption should vary directly with income. We obtained a positive coefficient that, while not large, suggests that the index excludes some important attributes and raises the possibility that the estimated prices are biased.

Despite income's significant and positive coefficient, the fact that the index excludes some attributes does not significantly bias the estimated coefficients. Income explains very little of the variation

*For example, plots of the residuals indicated that the squared specification for the number of bathrooms would fit the data better than a linear specification.

Table 4

STANDARD ERRORS FOR HEDONIC INDEXES FIT TO EXPERIMENTAL HOUSING ALLOWANCE PROGRAM DATA FOR RENTAL HOUSING

Institution and Housing Market	Standard Error of the Estimate	
	Amount ($/mo.)	Percent of Average Rent
Rand		
St. Joseph County, IN	24.55	18.4
Brown County, WI	20.00	15.3
Abt Associates		
Pittsburgh, PA	19.99	18.8
Phoenix, AZ	22.33	18.0
Urban Institute		
Pittsburgh, PA	23.98	28.9
Phoenix, AZ	29.90	29.5

SOURCE: Tabulated by the author from 1,129 records composed from baseline household, residential building, neighborhood, and landlord surveys for St. Joseph County, Indiana, and from data in C. Lance Barnett, *Using Hedonic Indexes to Measure Housing Quantity*, The Rand Corporation, R-2450-HUD, October 1979; Sally Merrill, *Draft Report on Hedonic Indices as a Measure of Housing Quality*, AAI-76-96R, Abt Associates, Cambridge, Mass., 23 December 1977; and Jeanne E. Goedert et al., *The Integrated Analysis of Housing Quality Improvements: Two Initial Approaches*, WP-216-15, The Urban Institute, Washington, D.C., 17 June 1975.

of the index's residual: The standard error of the estimate for this ancillary regression is $24.22 per month as opposed to $24.55 per month for the hedonic regression; and the R^2 is .005. Moreover, when income is included in the hedonic index, none of the estimated coefficients changes by more than one standard deviation.

The discussion above noted that the significance of the two location dummy variables implies that the index excludes some neighborhood variables. Again, the omission does not seem to bias the included variables' coefficients. When separate regressions were run for central South Bend and the rest of the county, the null hypothesis that the two

sets of coefficients were equal could not be rejected.* In essence this procedure, a method of testing for interactions between location and the other attributes, indicates that the excluded location variables are not highly correlated with the included variables, and that their omission does not seriously bias the estimated coefficients reported above.

*The *F*-statistic for the test did not exceed the critical value at the 99 percent confidence level. The small sample size prohibited performing the same test for the southeast suburbs.

III. ASSESSING THE INDEX'S PORTABILITY

We define perfect portability as having the same specification provide the best fit and the same attribute prices in both HASE sites. Perfect portability would allow HASE analysts to pool data for both sites, controlling for quantity or location differences. The single specification could be used to form either Laspeyres or Paasche indexes and calculate upper and lower bounds for price or quantity differences across sites.*

There is no reason to presume, however, that one hedonic index specification will fit both sites' housing markets equally well. Attribute prices represent the solution to the system of attribute supply and demand equations. Differences in either supply or demand conditions could lead to different coefficients, forcing us to apply one of the indexes to a market for which it is not the best specification. Such a situation would lessen the usefulness of cross-site analyses by lowering the accuracy of the quantity normalization or bounding procedures.

The two HASE sites were chosen for their contrasting housing markets and populations. Brown County's market has a low vacancy rate in the face of steadily growing demand. St. Joseph County's older housing stock is in worse repair, and population shifts since 1960 together with little net growth have led to extremely high vacancy rates--and even abandonment--in central South Bend. Whereas less than 2 percent of Brown County's population is nonwhite, one in ten St. Joseph County households is nonwhite, and most of those households are in central South Bend.

These differences allow a strong test of portability under differing market conditions. In this section, we compare the final specifications for St. Joseph and Brown counties so as to identify similarities

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*For a description of Laspeyres and Paasche indexes, their usage, and their shortcomings, see Franklin M. Fisher and Karl Shell, *The Economic Theory of Price Indices*, Academic Press, New York, 1972.

in attributes across the two sites. Then we compare coefficients for the same specification fit in both sites to see how much error such a procedure might introduce.

COMPARISON OF THE TWO SITES' INDEXES

Table 5 compares the attributes in each site's final index.* The two specifications comprise about the same number of variables--26 for St. Joseph County and 27 for Brown County--and have 14 variables in common.

The same two measures of housing space appear in both indexes--number of rooms and number of bathrooms. The specification of the latter, however, differs between the sites, bathrooms evidencing increasing marginal value in St. Joseph County but constant marginal value in Brown County. In Sec. II the St. Joseph County specification was explained in terms of supply costs: The age of the county's housing stock suggests that in many cases additional bathrooms were added to existing structures. This is consistent with the differences between the two counties, since in Brown County, with its newer stock, probably fewer bathrooms have been added after initial construction.

The Brown County index contains two-thirds more housing quality attributes than the St. Joseph County index, although six variables are common to both specifications. Building age serves as a proxy for both interior and exterior quality in St. Joseph County because interior and exterior quality ratings, which enter the Brown County index, did not perform well in St. Joseph County. This fact may result from the greater heterogeneity of St. Joseph County's population, resulting in less consensus about dwellings' quality there. If so, the ratings elicited by our surveys are probably less consistent among respondents in St. Joseph than in Brown County, a natural consequence of which would be insignificance of the ratings' coefficients in general.**

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*A detailed description of the Brown County specification appears in Barnett. For this comparison, I have collapsed his interior and exterior housing quality attributes into one group.

**Alternatively, the ratings may be consistent and the difference explained by the fact that St. Joseph County residents value housing quality less than do Brown County residents. People in St. Joseph

Table 5

HOUSING ATTRIBUTES AND PRICE ADJUSTMENT VARIABLES IN THE FINAL ST. JOSEPH AND BROWN COUNTY HEDONIC INDEXES

St. Joseph County, Indiana	Brown County, Wisconsin
Housing Space	
Number of rooms (ln) Number of bathrooms (squared)	Number of rooms (ln) Number of bathrooms
Housing Quality	
Number of appliances supplied by landlord (squared) Presence of thermostat Lot size per dwelling (1,000 square feet) Single-family dwelling Composite rating of comparative building quality Type of exterior wall material	Number of appliances supplied by landlord (squared) Presence of thermostat Lot size per dwelling (1,000 square feet) Single-family dwelling Composite rating of comparative building quality Type of exterior wall material
Building age (years) Building age (years squared) Presence of commercial unit in building	Composite rating of interior quality Presence of storage space Presence of central or steam heat Presence of subdivided residential space Composite rating of exterior quality Presence of garage or carport Duplex Five to nine dwellings on property Ten or more dwellings on property
Accessibility	
Generalized access to employment	Generalized access to employment
Neighborhood Quality	
Composite rating of neighborhood quality Located in southeast suburbs Located in central South Bend	Composite rating of neighborhood quality Fraction of neighborhood that is open space
Blockface Quality	
Presence of commercial land Presence of other residential land Presence of mixed residential and commercial land Presence of farmland Presence of abandoned buildings or vehicles Presence of vacant lots Composite rating of buildings, yards, and property maintenance Street maintenance	Presence of commercial land Presence of institutions Presence of above average landscaping
Price Adjustments	
Length of stay (years) Length of stay exceeding 3.5 years Presence of a resident landlord	Length of stay (years) Length of stay exceeding 3.5 years Presence of a resident landlord Tenant's satisfaction with dwelling

SOURCE: Table 2 above and C. Lance Barnett, *Using Hedonic Indexes to Measure Housing Quantity*, The Rand Corporation, R-2450-HUD, October 1979, Table 1.

The same measure of accessibility, generalized access to employment, is significant in both sites, as is the composite rating of neighborhood quality. However, the St. Joseph County index includes two dummy variables to indicate location in certain neighborhoods, whereas in Brown County, the fraction of total neighborhood area that is open space provides an additional measure of neighborhood quality.

Blockface quality attributes display a pattern opposite to that for housing quality attributes: The St. Joseph County index contains eight blockface quality variables, the Brown County index only three. One variable, presence of commercial land, is common to both. Most of the additional variables in St. Joseph County relate to land use.

Price adjustment specifications for the two indexes are nearly identical, the only difference being the inclusion of a tenant satisfaction variable in Brown County. Originally included to capture quality attributes that either were not measured or could not be quantified, satisfaction was later interpreted as a measure of how much of a bargain the tenant receives.*

COMPARISON OF THE BROWN COUNTY SPECIFICATION IN BOTH SITES

Table 6 compares the estimated coefficients for the Brown County specification fit to data for both markets. Coefficients for about a quarter of the index's 27 variables differ significantly (at the 95 percent confidence level) between sites. However, only one coefficient has different signs in the two sites.

Prices for both spatial attributes are significantly larger in St. Joseph County. Three of the 15 housing quality attributes exhibit significantly different prices in the two counties: number of landlord-supplied appliances, single-family dwelling, and presence of central or steam heat. Prices for the first two are higher in St. Joseph

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County may be more concerned with the quality of their neighbors and neighborhoods (see the comparison of location attributes below). The possibility that specification error is more prevalent in the St. Joseph County index must also be admitted. These are issues we would like to resolve (see Sec. V).

*For an explanation and interpretation of this variable, see Barnett.

Table 6

ESTIMATED COEFFICIENTS FOR THE BROWN COUNTY SPECIFICATION FIT TO ST. JOSEPH AND BROWN COUNTIES' HOUSING MARKETS

Independent Variables	Estimated Price ($/mo.)		*t*-value of Coefficient Difference
	St. Joseph County, Indiana	Brown County, Wisconsin	
Housing Attributes			
Space			
Number of rooms (lu)	59.16	46.70	3.32
Number of bathrooms	35.98	18.86	2.71
Interior Quality			
Composite rating of interior quality	2.27	5.07	1.24
Number of appliances supplied by landlord (squared)	2.56	1.11	5.43
Presence of storage space	1.53	3.95	.95
Presence of central or steam heat	-3.00	13.82	5.96
Presence of thermostat	9.37	9.90	.21
Presence of subdivided residential space	-1.11	-4.84	1.51
Exterior Quality			
Composite rating of exterior quality	5.64	5.60	.01
Composite rating of comparative building quality	2.22	5.80	1.22
Lot size per dwelling (1,000 square feet)	1.24	1.27	.06
Presence of wood or composition siding	-2.17	-6.08	1.80
Presence of garage or carport	.19	3.16	1.49
Single-family dwelling	12.72	3.81	2.46
Duplex	22.25	31.12	1.36
Five to nine dwellings on property	1.58	4.91	1.05
Ten or more dwellings on property	8.41	8.78	.08
Location Attributes			
Accessibility			
Generalized access to employment	9.28	7.86	.50
Neighborhood Quality			
Composite rating of neighborhood quality	17.26	9.39	1.96
Fraction of neighborhood that is open space	14.60	9.92	.57
Blockface Quality			
Presence of commercial land use	-3.44	-3.69	.13
Presence of institutions	-.58	-5.54	1.93
Presence of above average landscaping	8.06	5.03	.56
Price Adjustments			
Length of stay (years)	-4.72	-4.45	.32
Length of stay exceeding 3.5 years	3.73	3.86	.13
Tenant's satisfaction with dwelling	-1.74	-4.69	2.15
Presence of resident landlord	-5.70	-2.31	1.14
Other			
Constant term	-68.97	-35.58	2.21

SOURCE: Tabulated by the author from 1,129 records composed from baseline household, residential building, landlord, and neighborhood surveys for St. Joseph County, Indiana. Brown County, Wisconsin, data are from C. Lance Barnett, *Using Hedonic Indexes to Measure Housing Quantity*, The Rand Corporation, R-2450-HUD, October 1979.

NOTE: Analysis uses only data for dwellings whose occupants pay full rent and with complete information on the variables listed.

County, although the difference for appliances is not large (about 1 percent of average monthly gross rent).*

The presence of steam or central heat, however, increases monthly rent by nearly $14 in Brown County, and decreases it by $3 in St. Joseph County. This $17 per month difference represents 13 percent of average monthly gross rent. Neither separate dummy variables for the two types of heating system nor a rating of heating system quality (supplied by the tenant) yielded statistically significant coefficients in St. Joseph County. Given that winters in Indiana, like those in Wisconsin, can be severe, this lack of significance is puzzling.

The only location attribute whose coefficient differs significantly between the sites is the composite rating of neighborhood quality, with a larger value in St. Joseph County. Conversely, tenants' satisfaction with the dwelling, the only price adjustment variable to exhibit a significant difference, carries a smaller discount in St. Joseph than in Brown County, although the $3 difference represents only 2 percent of average monthly rent.

The constant terms also differ significantly. Normally, we would expect no constant term, so that setting all attributes to zero would produce a monthly rent of $0, i.e., dwellings that supply nothing command no rent. Incorrectly specified or omitted attributes could produce a nonzero constant, but tests of the Brown County specification indicated that such errors were not a problem.** Rather, the significant constant term arises from the fact that we do not know the true zero points for the quality variables. Although they are coded on interval scales with the lowest value represented by 0, we do not know whether our lowest quality category (poor) is equivalent to no quality. As reported above, the constant term is insignificant in the St. Joseph County index, which includes fewer rating variables.

A comparison of the standard errors of the estimates (see Table 7) indicates that the St. Joseph County specification performs slightly

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*The average monthly gross rent was almost identical for our two sites, being $133.46 in St. Joseph County and $137.42 in Brown County.

**See Barnett. Tests for specification error were run on the final St. Joseph County specification but not on the Brown County specification when it was fit to St. Joseph County data.

Table 7

PERFORMANCE OF HEDONIC INDEX REGRESSIONS IN ST. JOSEPH COUNTY, INDIANA, AND BROWN COUNTY, WISCONSIN

Index	Standard Error of the Estimate	
	$/Month	Percent of Average Rent
St. Joseph County specification[a]	24.55	18.4
Brown County specification in		
St. Joseph County	25.81	19.4
Brown County	20.00	15.3

SOURCE: Tabulated by the author from 1,129 records composed from baseline household, residential building, landlord, and neighborhood surveys for St. Joseph County, Indiana. Brown County data are from C. Lance Barnett, *Using Hedonic Indexes to Measure Housing Quantity*, The Rand Corporation, R-2450-HUD, October 1979.

[a]Only estimated in St. Joseph County.

better than the Brown County specification fit to the St. Joseph County housing market. However, the Brown County specification performs better in Brown County than either specification does in St. Joseph County.

IV. USING THE INDEX

This section investigates marginal expenditures for summary attribute groups by renters in different income categories. The analysis describes the patterns evidenced by our sample of renters. It does not, however, control for household characteristics other than income that affect expenditures, e.g., life-cycle stage. Nor does it explain how expenditures would change if a household's income were increased, as such an analysis would also have to consider tenure-change decisions, which could be systematically related to income changes. It does support the importance hierarchy presented in Sec. II, and the patterns described below are consistent with those frequently discussed in urban housing literature. Thus, the analysis further substantiates the plausibility of the hedonic index as well as illustrating one way in which the index can be used to analyze housing markets.

Expenditures for summary attributes were computed by multiplying the value of each component by its price and summing over all attributes in the category. Thus, expenditures for space equal \$59.19 times the natural logarithm of the number of rooms plus \$15.75 times the number of bathrooms squared.

The last column of Table 8 indicates that renters do not increase their expenditures for residential services by much as income increases.* Those with annual incomes of between \$12,501 and \$15,000 spend only \$24.22 more per month than those with annual incomes of between \$5,001 and \$7,500. Calculating from the midpoint of the intervals and converting to monthly income, we find that each extra dollar of monthly income increases the consumption of residential services by only \$.04. That figure is consistent with current income elasticities estimated using St. Joseph County data.**

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*The expenditure for residential services equals monthly gross rent plus the price discount that accrues with length of stay and that is due to the presence of a resident landlord, i.e., the price adjustments.

**See John E. Mulford, *The Income Elasticity of Housing Demand*, The Rand Corporation, R-2449-HUD, July 1979. He estimates the current income elasticity of expenditures to be .11 for renters. Assuming an average expenditure share of .25, the implied marginal propensity to consume is .03.

Table 8

MARGINAL EXPENDITURES ON SUMMARY ATTRIBUTES AS INCOME INCREASES: HOUSEHOLDS WITH ANNUAL INCOMES OVER $5,000

Income Category ($/yr.)	Marginal Expenditure ($/mo.) Relative to Low-Income Families[a]			
	Space[b]	Quality[b]	Location[b]	Residential Services[c]
5,001- 7,500	-1.43	-.49	1.07	-.86
7,501-10,000	3.96	6.60	.37	10.92
10,001-12,500	5.76	11.54	-.38	16.92
12,501-15,000	9.14	13.10	1.11	23.36
15,000+	13.78	27.64	3.01	44.43

SOURCE: Tabulated by the author from 1,129 records composed from baseline household, residential building, landlord, and neighborhood surveys for St. Joseph County, Indiana.

NOTE: Table entries are computed by subtracting average predicted expenditure for families whose annual income is less than $5,001 from remaining average predicted expenditure.

[a] Defined here as families whose annual income is less than $5,001.

[b] See Table 2 for attributes in each hedonic good.

[c] Predicted gross rent plus price adjustments.

Table 8 shows that as income increases, renters purchase additional space and additional quality. The marginal expenditures on quality, however, are larger than those on space. Marginal expenditures for location are not large and do not increase monotonically with income.

Table 9 breaks location attributes into three subcomponents: employment access, neighborhood quality, and blockface quality. As income increases in the lower part of the range, households forgo employment accessibility in favor of better neighborhoods. In the upper range there is little change in the amount spent for accessibility, but renters continue to spend more for better neighborhoods. Expenditures on blockface quality vary little as income changes. Together, these patterns explain the U-shaped marginal expenditure curve for location attributes.

Table 9

MARGINAL EXPENDITURES ON LOCATION ATTRIBUTES AS INCOME INCREASES: HOUSEHOLDS WITH ANNUAL INCOMES OVER $5,000

Income Category ($/yr.)	Marginal Expenditures ($/mo.) Relative to Low-Income Families[a]			
	Access to Employment	Neighborhood Quality[b]	Blockface Quality[b]	Location[c]
5,001- 7,500	-.47	.86	.68	1.07
7,501-10,000	-2.82	2.21	.98	.37
10,001-12,500	-3.77	2.76	.64	-.38
12,501-15,000	-3.06	3.02	1.16	1.11
15,001+	-2.54	5.48	.07	3.01

SOURCE: Tabulated by author from 1,129 records composed from baseline household, residential building, landlord, and neighborhood surveys for St. Joseph County, Indiana.

NOTE: Table entries are computed by subtracting average predicted expenditure for families whose annual income is less than $5,001 from remaining average predicted expenditure.

[a] Defined here as families whose annual income is less than $5,001.

[b] See Table 2 for attributes in each hedonic good.

[c] Expenditure on location equals the sum of expenditures on access to employment, neighborhood quality, and blockface quality.

V. CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

The St. Joseph County hedonic index contains 26 independent variables--measures of space, housing quality, and location, as well as three price adjustment terms. Quality attributes rank most important, followed closely by space; location is least important. This ranking is substantiated by the analysis of marginal expenditure patterns presented in Sec. IV. The index does not include any measures of neighborhood service or amenities, and interior and exterior quality ratings were insignificant, requiring the use of building age as a quality proxy. The index performs well compared with most others, with an R^2 of .64 and a standard error that is 18 percent of average monthly gross rent.

Plots of residuals showed that the independent variables are specified properly to ensure constant marginal prices. Tests indicated that although the present index is missing some important attributes, the omitted variables are apparently not highly correlated with the included ones, so that their omission should not seriously bias the estimated attribute prices.

The hedonic index is surprisingly portable given the differences between the two housing markets. Over half of the variables in each site's index appear in the other. When the Brown County specification was fit to data for both counties, only one coefficient had different signs, and over three-fourths of the independent variables had statistically indistinguishable coefficients.

The dissimilarities, however, must not be overlooked. Market differences led to different specifications for the number of bathrooms, even though the variable appeared in both indexes. Nearly half of the variables in each site's index were unique to it, and although they fell in the same summary categories, their composition differed--more blockface quality attributes in St. Joseph County, more housing quality attributes in Brown County. Indeed, the composite interior and exterior quality ratings, which worked well in Brown County, were insignificant in St. Joseph County and had to be replaced with a proxy

for quality. When the specification was fit to both sites, a quarter of the coefficients exhibited significant differences, large enough (up to 13 percent of average monthly gross rent) to have a substantial impact on the index's predicted values.

We must conclude that market conditions do affect the composition and coefficients of a hedonic index. Although the differences are less drastic than expected, one should be cautious about transferring indexes from one market to another.

Finally, the statistics presented earlier (see Table 7) suggest that any reasonable specification would perform better in Brown than in St. Joseph County. That conclusion is consistent with the fact that Brown County's housing market appears to be closer to longrun equilibrium (real value did not change significantly over the 13-year period ending with 1973, indicating a running balance between supply and demand) than St. Joseph County's (real value dropped by nearly 19 percent between 1961 and 1971).* The better fit in Brown County is consistent with our earlier point that the efficiency of OLS estimators for random coefficients depends on how close the market is to equilibrium. However, one of the tests presented in Sec. II indicated that some important attributes are still missing from the St. Joseph County specification. We hope that further empirical work will identify and include some of these in the index** and thus improve its performance.

Applying the St. Joseph County index's coefficients to expenditures for housing attribute groups showed that renters' marginal expenditures for quality are larger than those for space, i.e., renters have a

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*_Third Annual Report of the Housing Assistance Supply Experiment_, The Rand Corporation, R-2151-HUD, February 1977, pp. 67-70. Because St. Joseph County could contain submarkets that are in shortrun equilibrium, we tested for the two most likely submarkets--central South Bend and the rest of the county. The test is the same as that reported in Sec. II for assessing specification error: The null hypothesis that the coefficients for the two regressions were equal could not be rejected at the 99 percent confidence level.

**We do not expect that improving the specification will drastically improve its performance. Rather, the future work is intended to resolve some of the anomalies indicated in this paper and obtain better housing quality and neighborhood variables.

greater propensity to rent better dwellings than they do to rent larger ones as income increases. The lack of any clear pattern with respect to location derives from the fact that renters trade accessibility for neighborhood quality as income increases. Expenditures for blockface quality showed almost no change across income groups.*

Although the marginal expenditure analysis is not definitive, it demonstrates how a hedonic index can be used. So far, the analysis fails to control for other household characteristics that affect the demand for summary attributes (e.g., family size affects the demand for space).

The additional housing and location attributes that were tested but not used were eliminated because their coefficients were insignificant. Although they did not perform well individually, many of them represent dimensions of housing that common sense indicates ought to matter. Their insignificance is probably due to multicollinearity or measurement error. The first makes it difficult to measure the contribution of individual components, and the second tends to bias estimates toward zero.

Indeed, the HASE data, which include many sets of variables that measure similar attributes, exhibit much collinearity. We plan to explore methods of aggregating similar variables into a more tractable number of meaningful, less collinear attributes. Factor analysis, for example, might prove a useful tool.

Our data base contains many area ratings provided by tenants and landlords. Few of these variables remained in the hedonic index, perhaps because the individual ratings are very "noisy." We plan to replace individual ratings with neighborhood averages to remove the noise from such variables.

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*These results pertain only to different income classes of renters in our sample. As its income increases, a particular household could change tenure, simultaneously increasing its expenditures for neighborhood and blockface quality (if these items are systematically higher for homeowners). The results of the expenditure analysis, however, remain unchanged: Higher income renters do not spend much more for location than do lower income renters.

The HASE data include a number of variables measuring the incidence of crime in South Bend, none of which yielded useful coefficients.* Part of the problem may have been the lack of crime data for the remainder of the county, where the variables were set equal to 0. We plan to estimate crime rates for areas outside of South Bend and to use an index that weights together the various crime measures.

Finally, we will search for additional housing and neighborhood quality measures as well as means of aggregating them. If building age were adjusted to account for the discontinuities caused by major renovation, it could be a good instrumental variable for quality. The HASE data base contains a number of neighborhood service and amenity measures that may aggregate into new neighborhood quality variables, although we do not think these will be highly significant in St. Joseph County. However, variables describing neighborhood residents--racial and ethnic composition, median income, and so on--should increase the data's explanatory power and help control for neighborhood differences.

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*Kain and Quigley had the same result when they included crime data in their hedonic index for St. Louis.

APPENDIX

Table A.1

MEANS AND STANDARD DEVIATIONS FOR VARIABLES USED TO FIT A HEDONIC INDEX FOR RENTAL DWELLINGS: ST. JOSEPH COUNTY, INDIANA, 1975

Variable	Range of Values	Statistics	
		Mean	Standard Deviation
Dependent			
Gross rent ($/month)	45-365	133.46	40.68
Housing Attributes			
Space			
Number of rooms (ln)	0-2.4	1.35	.32
Number of bathrooms (squared)	0-9	1.07	.43
Quality			
Number of appliances supplied by landlord (squared)	0-25	4.07	4.63
Presence of thermostat	Yes = 1, no = 0	.67	.47
Building age (years)	1-124	60.84	23.02
Building age (squared)	1-15,376	4,231.10	2,548.60
Lot size per dwelling (1,000 square feet)	1-10.9	3.09	2.32
Single-family dwelling	Yes = 1, no = 0	.17	.37
Composite rating of comparative building quality	0-2	1.04	.40
Presence of commercial unit in building	Yes = 1, no = 0	.03	.18
Presence of brick or stone exterior	Yes = 1, no = 0	.14	.35
Location Attributes			
Accessibility			
Generalized access to employment	0-2.6	1.97	.51
Neighborhood Quality			
Composite rating of neighborhood quality	0-3	1.84	.24
Located in southeast suburbs	Yes = 1, no = 0	.01	.10
Located in central South Bend	Yes = 1, no = 0	.60	.49
Blockface Quality			
Presence of other residential land	Yes = 1, no = 0	.98	.14
Presence of mixed residential and commercial land	Yes = 1, no = 0	.14	.35
Presence of farmland	Yes = 1, no = 0	.02	.13
Presence of abandoned buildings or vehicles	Yes = 1, no = 0	.13	.34
Presence of vacant lots	Yes = 1, no = 0	.52	.50
Presence of commercial land	Yes = 1, no = 0	.38	.49
Composite rating of buildings, yards, and property maintenance	0-3	1.39	.42
Street maintenance	0-3	2.28	.60
Price Adjustments			
Length of stay (years)	0-44.0	2.80	4.82
Length of stay exceeding 3.5 years	0-40.5	1.28	4.07
Presence of a resident landlord	Yes = 1, no = 0	.13	.34

SOURCE: Tabulated by the author from 1,129 records composed from baseline household, residential building, landlord, and neighborhood surveys for St. Joseph County, Indiana.

NOTE: Analysis uses only data for dwellings whose occupants pay full rent and with complete information on the variables listed.

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